# GREENHOUSE GAS FROM DAIRY MANURE MANAGEMENT AT THE FARMSTEAD

## Part 10: GHG reduction from an anaerobic digestion system

February 2022 (Revised)

**Revision Note: Updated values, equations, and tables to match 2019 IPCC Report and 2022 CLCPA Report.**

An anaerobic digestion system (ADS) is designed to produce and capture methane ($CH_4$) in the form of biogas that typically fuels an engine generator set to generate renewable electricity. An ADS both reduces $CH_4$ emission from manure storage by combusting the captured $CH_4$ to reduce its global warming potential (GWP) and producing renewable energy displacing fossil fuel.

The stored effluent may continue to emit up to 20% more $CH_4$ since the temperature and bacterial populations are initially the same in the storage as in the digester, and there are remaining volatile solids (VS) that have not been digested. Many dairy farms separate undigested solids using a solid-liquid separation system (SLS) after the digester. This further reduces the VS loading to the effluent storage.

**Advantages**

There are many benefits of farm-based ADS including: renewable energy production, increasing the potential for off-farm sales of by-products, recycling of nutrients, and improving water and air quality. The ADS eliminates $CH_4$ emissions of all the $CH_4$ that is contained while also displacing fossil fuel by utilizing the renewable energy in the captured biogas.

**Considerations**

Managing the complex and expensive ADS requires a dedicated management effort. Not all ADS are managed to maximize $CH_4$ destruction. If excessive $CH_4$ is allowed to leak or is not combusted and/or if the effluent storage continues to produce excess additional $CH_4$, the resulting GHG impact may be negative. The potential to emit excess $CH_4$ exists when 1) ADS leaks occur, 2) the engine-generator set, boiler, and/or or flare are not operated efficiently, and/or 3) if the effluent storage continues to produce uncontained $CH_4$.

**Cost**

The costs and benefits of anaerobic digestion are quite complex. Capital costs of turnkey ADS vary but can range from $4,000 to $5,500 per kW of generation capacity. Operating costs from existing systems have been estimated at $0.03 per kWh generated.

**Planning considerations**

Careful calculations need to be made when planning for an ADS. The utility needs to be consulted to determine how/if the distribution lines to the farm can handle electricity sold. A design professional should be consulted when considering an ADS.

The GWP can be calculated by using equation 1.2 from fact sheet 2 and equation 1.3 from fact sheet 3. Table 1.10 shows the MCF, $EF_3$, and GWP as the carbon dioxide equivalent ($CO_2eq$) per cow per year for a manure storage without a natural crust and a liquid storage system with an ADS where the digestate is followed by a SLS system removing 50% of the remaining VS. The MCF for an ADS is 1. The MCF for the effluent storage from an ADS is estimated to be the same as from a liquid storage. The ADS would also include digestate separated solid storage. The separated solids in these systems may be managed in several different ways. Variations in ADS performance, liquid and solid storage will change the GWP.

An additional GWP reduction will occur with the production of renewable energy. Assuming a 38% efficient engine and typical ADS performance, 1,955 kWh of electricity will be produced annually per cow, reducing a US average of 1.55 lbs. of $CO_2eq$/kWh for the fossil fuels avoided (Wright and Gooch).

**Table 1.10. Global warming potential (GWP) estimates[2] for liquid storage without a crust compared to an anaerobic digestion system (ADS), including a solid liquid separation for the digestate effluent, a solid storage for the separated solids, liquid storage for the separated liquid, and fossil fuel carbon dioxide avoided.**

| MCF[1] (winter - summer) | $EF_3$[1] | Manure Management Practice | Annual GWP lbs. from $CH_4$ $CO_2$eq/cow/yr.[2] | Annual GWP lbs. from $N_2O$ $CO_2$eq/cow/yr.[2] | Total Annual GWP lbs. $CO_2$eq/cow/yr.[2] |
|---|---|---|---|---|---|
| 21 | 0 | Liquid/Slurry without natural crust | 5,504 | - | 5,504 |
| 1 | 0.0006 | Anaerobic Digestion System[3] | 262 | 102 | 364 |
| 21 | 0 | ADS Effluent Storage after SLS | 826 | - | 826 |
| 2 | (see ADS) | Solid Storage | 36 | - | 36 |
| N/A | N/A | Fossil fuels avoided with electricity | - | - | (3,024) |

[1]Source: IPCC (2019)
[2]Calculated
[3]Nitrous oxide emission (calculated from $EF_3$) is mainly from storage of digestate (IPCC, 2019).

Additional assumptions used are that each manure management system stores manure for both the summer period and the winter period, the nitrogen content of the manure excreted is 0.99 lbs./cow-day and the VS in raw manure is 16.9 lbs./cow-day (ASABE), SLS will divide the VS remaining after digestion, 5.1 lbs./cow-day, by 50% into each of the solid and liquid storages, the separated solids are stored in a static storage and the climate zone is "cool temperate moist".

The total GWP from an ADS using a SLS on the effluent and storing the separated solids in a static pile and the separated liquids in an uncovered storage and including the fossil fuels avoided because of renewable electricity production is 364 + 826 + 36 + (3,024) = (1,798) lbs. $CO_2$eq per cow per year.


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**FACT SHEET SERIES: 1 HOW ARE GREENHOUSE GASES GENERATED?, 2 DAIRY MANURE MANAGEMENT IMPACT ON METHANE, 3 DAIRY MANURE MANAGEMENT IMPACT ON NITROUS OXIDE, 4 COMBINING METHANE AND NITROUS OXIDE EMISSIONS FROM DAIRY MANURE MANAGEMENT AT THE FARMSTEAD, 5 GHG REDUCTION FROM CRUSTS ON STORAGES, 6 GHG REDUCTION FROM LIMITING SUMMER STORAGE, 7 GHG FROM SOLID STORAGE SYSTEMS, 8 GHG REDUCTION FROM SOLID/LIQUID SEPARATION, 9 GHG REDUCTION FROM AN IMPERMEABLE COVER, 10 GHG REDUCTION FROM AN ANAEROBIC DIGESTION SYSTEM.**


## References


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